Parametric Study of the Column Oil Agglomeration of Fly Ash

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ABSTRACT

A promising oil agglomeration method has been developed for the beneficiation of fly ash using a six-foot agglomeration column. Carbon concentrates have been isolated in yields greater than 60 % and purities of 55-70 %. The parameters studied include agitation speeds, airflow rates, slurry feed rates, solvent/ash ratios, and the use of various solvents as agglomerating agents. The effects of these variables on the quality of separation are discussed.

INTRODUCTION

The 21st century will demand environmentally clean and cost effective fuels for the generation of electricity within the United States. Coal is our most abundant fossil fuel in the US and therefore will play a critical role as a major source of energy in the 21st century [1]. However, electricity generated by coal combustion results in the increased emission of air pollutants such as NO_x and SO_x into our atmosphere, which leads to an increase in the formation of smog and acid rain. The Clean Air Act of 1990 requires the reduction of these types of gases into our atmosphere, which led to the application of low-NOx burners and catalytic reduction systems in the utility industry. Although low-NOx burners and catalytic reduction systems are effective in the reduction of NOx, they cause an increase in the amount of carbon in the coal combustion by-products (CCBs) generated under these conditions [2,3]. These CCBs mainly consist of fly ash with unburned carbon produced by the lower combustion temperatures required for the operation of the low-NO_x burners. Due to the limited applications of these high carbon fly ashes, they are being placed in landfills which is also detrimental to our environment. Consequently, it is critical that new technologies be developed which will allow for these high carbon fly ashes to be utilized more efficiently.

These high carbon fly ashes can be beneficiated by both dry and wet separation processes such as electrostatic separation [4], air classification [5] and froth flotation [6]. A similar agglomeration method utilized for coal beneficiation [7] was employed for the development a novel process for the recovery of unburned carbon from fly ash. Since most agglomeration methods are less sensitive to particle size and the oxidative state of the surface of the particle, it is assumed that this method should be successful for the recovery of unburned carbon from fly ash. This paper discusses the optimum parameters utilized for the operation of an agglomeration column for the beneficiation of high carbon fly ashes.

EXPERIMENTAL PROCEDURES

Samples A fly ash containing unburned carbon was collected from the bag house of the 500 lbs./hr combustion unit at the Federal Energy Technology Center (FETC). The fly ash sample examined in this study was obtained from the combustion of a Pittsburgh seam coal from the Black Creek mine. The analyses of these samples are shown in Table 1.

Table 1: Analysis of Raw Coal and FETC Fly Ash (Weight % Basic)

Sample	Black Creek Coal	FETC Fly Ash
Ash	9.23	89.56
Hydrogen	5.25	0.47
Carbon	74.67	9.50
Total Sulfur	1.49	0.70

Column Batch Mode Operating Conditions These conditions were predetermined during the initial developmental stages of this process. These described operating conditions will be used as our initial testing conditions for the optimization of this process. Figure 1 shows the operational flow chart for the six-foot agglomeration column that was tested under batch mode conditions. As shown in Figure 1, the experimental setup consisted of a 6 foot by 4 inches Plexiglas column equipped with a variable speed electrical motor, a slurry tank equipped with a variable air motor, a solvent recovery tank and 60 mesh stainless steel screen. Initially, the solvent and fly ash slurry was prepared at about a 5:1 weight ratio and conditioned for two minutes before it was pumped into the column at the feed rate of 930 ml/min. During the course of these tests the agitation speed was maintained a 400-rpm with airflow of 189 ml/min. The overflow unburned carbon product was collected on a 60-mesh screen, air-dried and analyzed to determine its purity. All of the carbon yields were calculated on a total weight carbon basis present in the feed fly ash.

RESULTS AND DISCUSSION

A systematic study of the effects of solvents, agitation speed, airflow, slurry feed rate and solvent/ash ratio on the quality of the beneficiated carbon products was conducted to determine the optimum operating conditions for this process.

Figure 2 shows the effects of various solvents on the recovery of unburned carbon from fly ash. The solvents that were tested were pentane, hexane, cyclohexane, and heptane. The best performing solvent under these conditions was cyclohexane, which resulted in a final carbon concentrate with the purity of 56.8 % at a 71.2 % carbon yield. It is speculated that the dispersion and the hydrophobicity properties were the major factors controlling the effectiveness of the performance of these solvents in this process. A better solvent recovery of 90 % was achieved with heptane along with lower carbon purity due to the longer carbon chain length and lower dispersion properties. Consequently, cyclohexane was selected as the solvent for the remaining tests. In all experimental cases, the cyclohexane recovery ranged from 81.0 to 88.0 percent regardless of the operating conditions.

The purity and yield of the carbon products were greatly influenced by the agitation speed. Figure 3 shows that the higher agitation speeds resulted in purer carbon products at the expense of the yields. Furthermore, it was observed that higher dispersion rates interfered with the coalescence of the carbon agglomerates. These conditions also improved the carbon/solvent interactions resulting in a purer carbon product. The agitation speed range for the optimum recovery of unburned carbon from fly ash was found to be between 400 to 500 rpm.

With the introduction of air into this process, it is assumed that it will have a direct effect on the parameters associated with the formation of the carbon/solvent agglomerates. Consequently, the unburned carbon yields and cyclohexane recoveries were examined as a function of column airflow. The purity of the unburned carbon was in the range of 65-71 percent during the course of these tests. Figure 4 indicates that higher airflows were detrimental to the formation of agglomerates resulting in lower carbon yields. These lower yields maybe attributed to the high turbulence generated as a result of the increase in the number of air bubbles present in the column under these high airflow rates. However, there was a slight improvement in the recovery of cyclohexane with the presence of air. The observed optimum range for the airflow for this process was determined to be between 175 and 300 ml/min.

The effects of slurry feed rates on the unburned carbon yield and cyclohexane recovery are illustrated in Figure 5. The purity of the carbon remained in the range of 68 to 71 percent during the course of these tests. Figure 5 shows that the carbon yields and cyclohexane recoveries were significantly decreased when the slurry feed rate was greater than 1000 ml/min. It is probable that the optimum loading rate for the agglomeration of unburned carbon for fly ash was achieved under these conditions.

Finally, the cyclohexane/ash ratio was varied under the initial batch mode operating conditions. A carbon product with the purity of 71.2 % in a yield of 56.8 %was obtained at the optimum cyclohexane/ash wt. ratio (grams/grams) approximately at a 5:1. Figure 6 indicates that all of the other ratios tested were not beneficial for the agglomeration of unburned carbon from fly ash. This demonstrates that there is a critical solvent/solid interaction present in the column agglomeration process. The observed optimum cyclohexane/ash wt. ratio range is 4:1 - 5:1. Furthermore, the best solvent recoveries were achieved under these conditions. However, the use of higher levels of solvents is economically undesirable.

CONCLUSION

In summary, the optimum operating conditions for the recovery of unburned carbon with purities ranges of 66 to 71 % and yields of 55-57 % from fly ash in this six-foot column agglomeration process are as follows.

- Solvent: Cyclohexane
- Agitation Speed Range: 400-500 rpm
- Air Flow Range: 175-300 ml/min.

- Slurry Feed Rate: 800-1000 ml/min.
- Solvent/Ash Wt. Ratio: 4:1-5:1

The critical factors for the success of this process are the solvent selection, solvent recovery, agitation speed, and solvent/ash ratio. The above ranges are recommended for the optimum recovery of unburned carbon from fly ash using this column agglomeration process.

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FIGURES

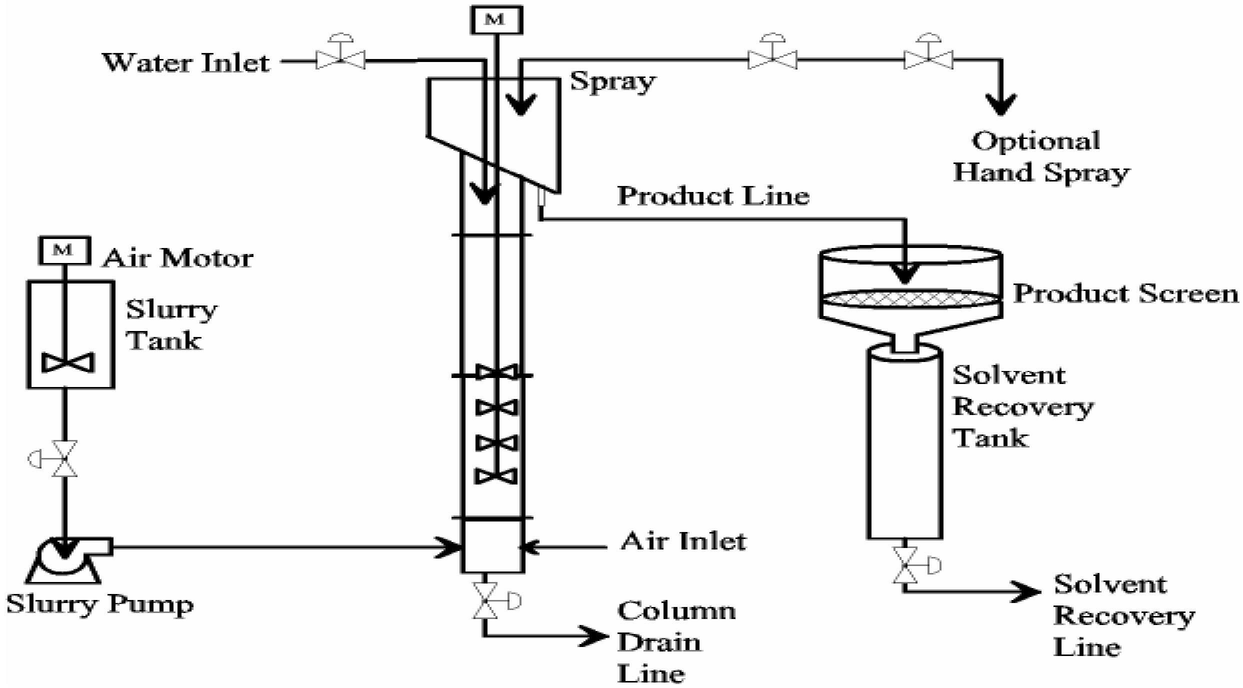

Figure 1: Operational Flow Chart for Six Foot Agglomeration Column

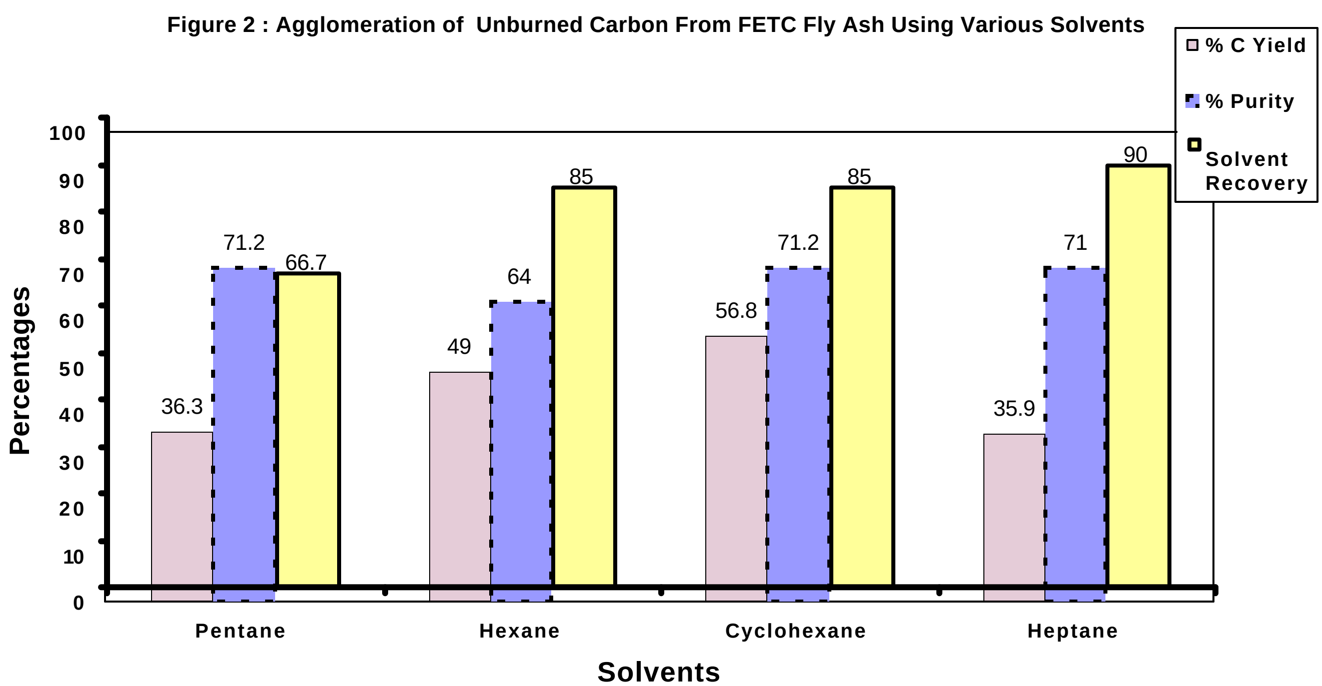

Figure 3: Agglomeration Recovery of Unburned Carbon from FETC Fly Ash at Various Agitation Speeds

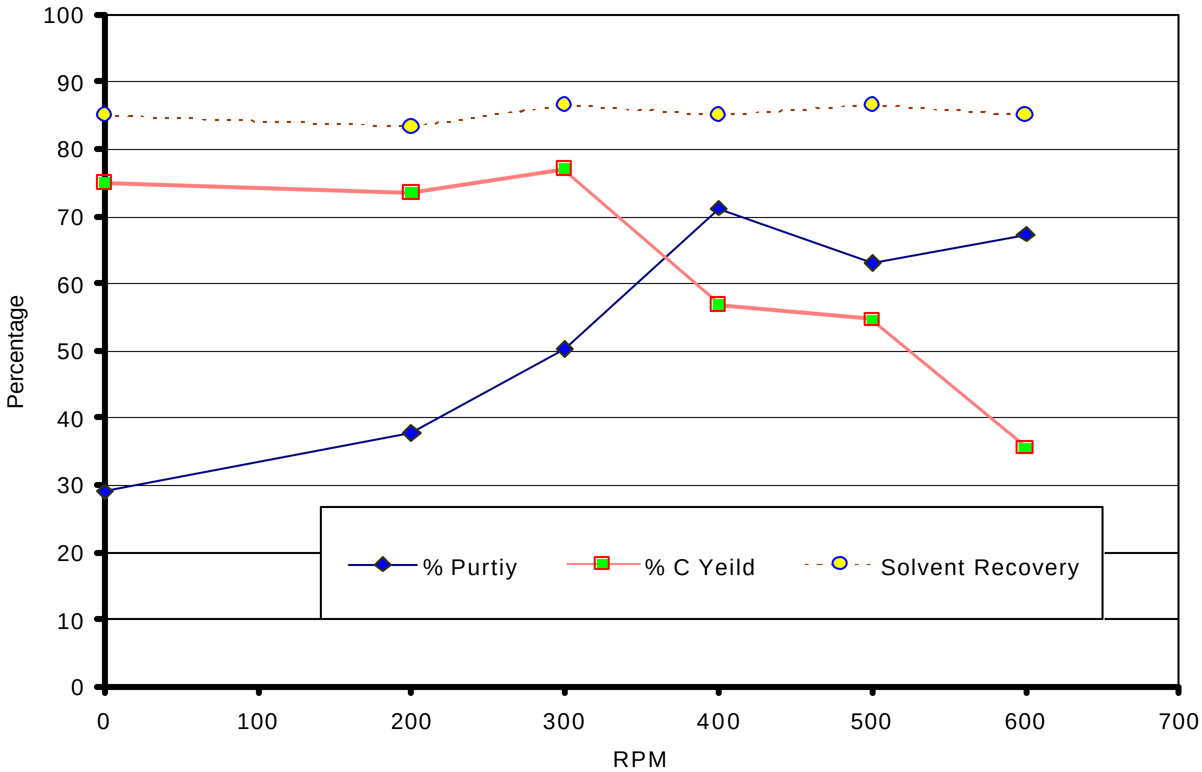

Figure 4: Agglomeration Recovery of Unburned Carbon from FETC Fly Ash at Various Air Flows

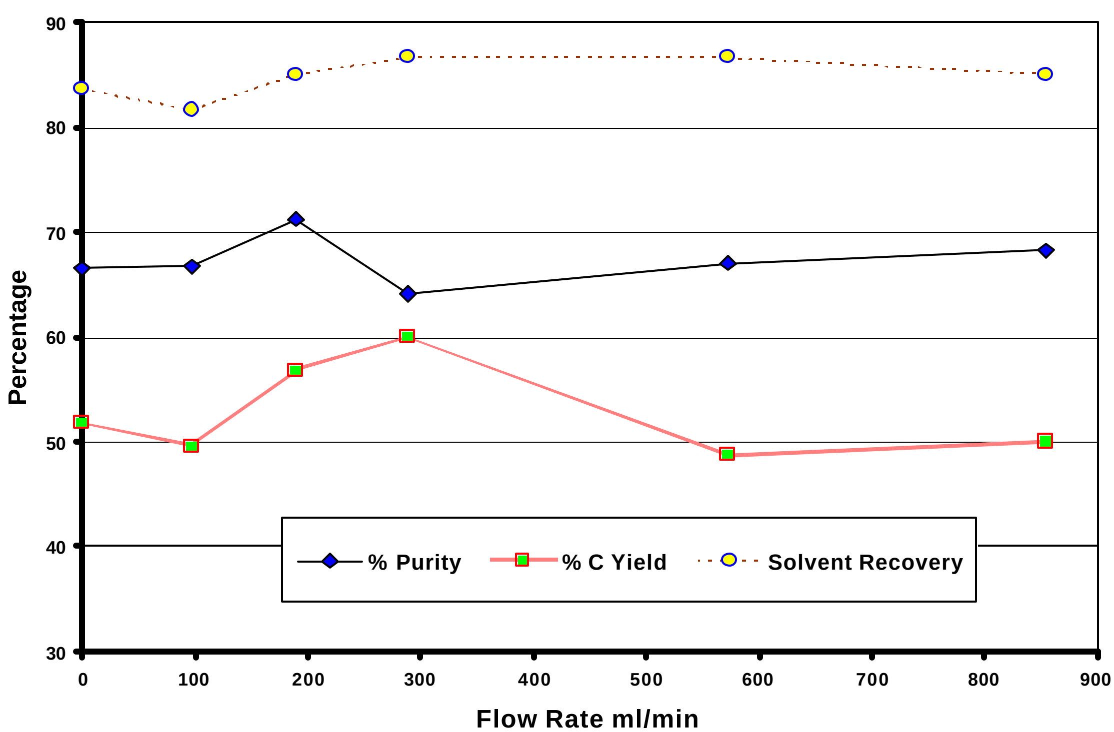

Figure 5: Agglomeration Recovery of Unburned Carbon from FETC Fly Ash at Various Slurry Feed Rates

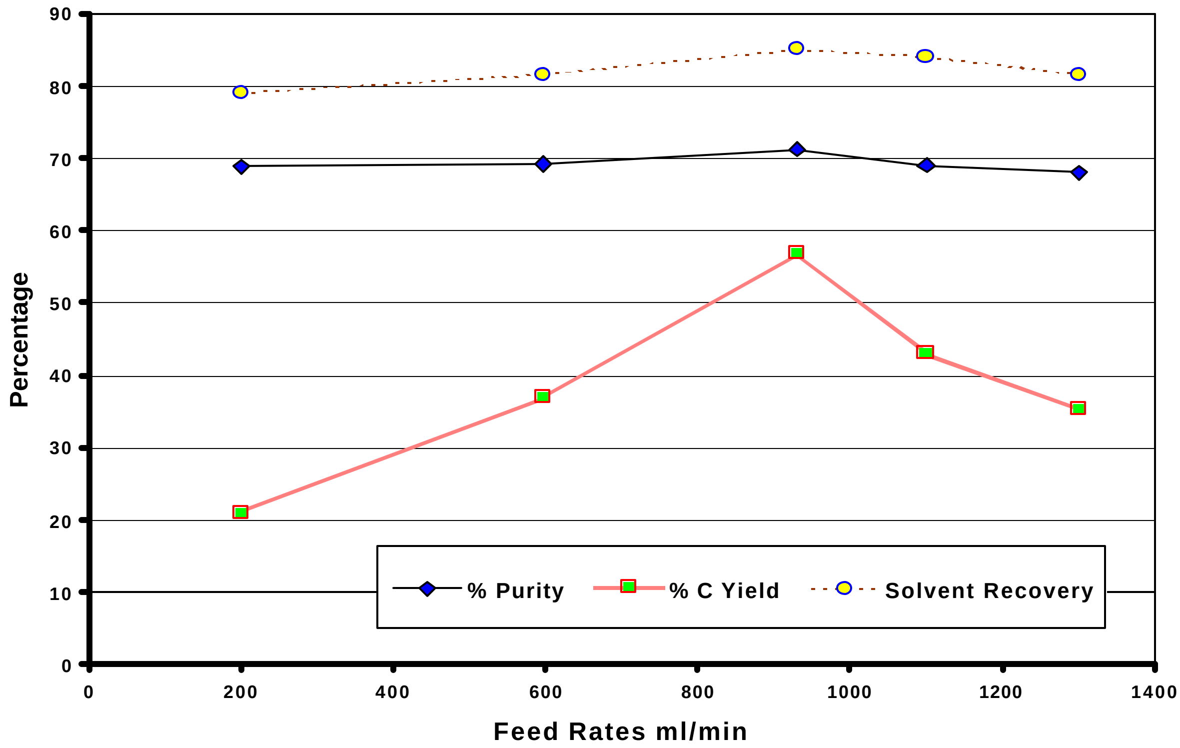

Figure 6: Agglomeration Recovery of Unburned Carbon from FETC Fly Ash at Various Solvent/Ash Weight Ratios